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REPORT LAYOUT + DESIGN: Sarah Jean Roberts (www.henn.com) (www.pinkcloud.dk)
"Our aim is to design better buildings and cities. We believe that a strong integrated research effort is imperative to develop innovative design solutions for the future. Therefore we aim to make research an integral part of our design process."

- Prof. Dr.-Ing. Gunter Henn

The Design Research Exchange (DRX) provides an open platform to unite experts from various fields. By exploring architectural topics of shared interest, the DRX promotes multi-disciplinary discussion between academics and professionals.

We envision the DRX as an ideal environment for the advancement of fresh ideas and fertile ground for experimentation. The DRX is a powerful tool for examining and advancing architectural techniques and methods, testing new technologies and materials, and informing our future built environment.

Prof. Dr.-Ing. Gunter Henn
HENN Founder + CEO
(MIT, TU Dresden)

Design Research Exchange
DRX Introduction

Initiated by Moritz Fleischmann (HENN Research Director) and Martin Henn (HENN Design Director), the Design Research Exchange, or DRX, is a non-profit residency program for young researchers. Hosted by HENN StudioB in Berlin, the eight-week annual event invites experts to present public lectures and provide critical feedback and guidance for young researchers.

While working in teams on an appointed topic, DRX Researchers have opportunities to join discussions, workshops, and lectures while gaining insight into HENN competitions. This year’s DRX 2012 included four DRX Experts and eight DRX Researchers with academic backgrounds in architecture, engineering, math, and computer programming. Together they formed a rich combination of knowledge and mutual interests.
The focus of the DRX 2012 was Minimal Surface High-Rise Structures. High-rise buildings are extremely complex architectural typologies, as they combine multiple systems including program, structure, circulation, MEP and façade in one highly integrated arrangement. The complexity of this task requires a cross-disciplinary, collaborative approach from the very early phases. This calls for innovative and novel design solutions.

**MINIMAL SURFACE STRUCTURES**

Structures derived from minimal surfaces have led to the design of various building typologies, such as tension-active roof structures, compression-active shells and large-scale architectural systems. But minimal surface structures remain virtually unexplored for applications in high-rise design. Minimal surfaces, as visible in various natural systems, have great potential for application in high-rise building design due to their structural efficiency, overall area minimization, and efficient material distribution. Minimal surfaces may present intriguing potential as an effective alternative design solution for high-rise structures.

**KEY QUESTIONS**

- Which minimal surfaces have potential as compression-active structural elements?
- At which scale do certain minimal surfaces work as structural components?
- How do minimal surface elements connect to a larger structural framework?
- Can surface-active structures and vector-active structures be integrated?
- How can the functional integrity of the building be maintained, and which materials would be appropriate?

**PHASE I: RESEARCH** (1 week)

Phase I comprised an introduction to minimal surfaces. The research was carried out in two teams. Team 01 explored mathematical descriptions of minimal surfaces and how they could be modeled for usage in "real-world" computer-aided design scenarios. Team 02 investigated spatial and structural models derived from minimal surfaces in design and nature with a focus on application in high-rise building design.

**PHASE II: EXPERIMENTATION** (2.5 weeks)

In Phase II, new teams were formed to distribute the knowledge gained from Phase I. Each team developed a structural system of 500m height based on minimal surfaces. The introduction of scale resulted in an exploration of building material, fabrication and assembly.

**PHASE III: PROTOTYPE** (3.5 weeks)

In Phase III, the context of high-rise building and its specific demands were introduced. The aim was to formulate a sensibility for the critical aspects of a high-rise building beyond its structure, namely its infrastructure, program, and skin. The ultimate aim was to develop an integrated architectural system.

The primary aim of the three phases was the development of three different high-rise structure proposals based upon the set framework of minimal surfaces.
2.3 // DRX 2012 LECTURES

DRX 2012 public lectures were presented by DRX Principals and Experts with diverse academic backgrounds. Lectures demonstrated their specific experience and interest in the appointed topic "Minimal Surface High-Rise Structures", fostering discussion and promoting free exchange of ideas across disciplines.

OPENING EVENT

At the DRX 2012 Opening Event, Prof. Dr.-Ing. Gunter Henn (Henn/TU Dresden) introduced the DRX program and structure with Principals Moritz Fleischmann and Martin Henn. Lectures presented at the opening by DRX 2012 Experts included "Experiments in Force Flow: Design by Research" by Prof. Dr. Toni Kotnik and "Hyper High-Rise Structures" by Prof. Dr. Patrick Teuffel.

02. DRX 2012 OPENING, 16 July 2012, Berlin DE / Lecture by Toni Kotnik / Photograph by Daniel da Rocha

2.4 // DRX 2012 WORKSHOPS

DRX Workshops are arranged to educate DRX Researchers and interested Experts in useful methods, techniques, and software applications. The aim of including workshops in the program is to enrich the skillsets of all participants by demonstrating tools for successful experimentation. DRX 2012 Tutors were invited to hold specialized workshops to develop new skillsets and understanding for the DRX 2012 focus topic.

03. DRX 2012 WORKSHOP, DRX Tutor Peter Debney / GSA workshop: “Form Follows Force - Soap Films and Geometric Optimization”
Each phase of the DRX 2012 concluded with a presentation of each team’s progress. The work was carried out in small groups with the chance to join another group at the end of each phase. Handouts were provided for each phase with specific materials, references, a reading list, possible techniques, and a detailed description of the intended goal, in addition to the necessary output.

At the mid-point and closure of the eight-week period, DRX Researchers presented their work in the form of public exhibitions with external critics and reviewers. Jury members included Mirko Becker, Eva Hinkers, Daniel Lordick, Tobias Nolte, and Alex Reddihough.
To conclude the DRX 2012, a final exhibition and presentation of the program results was held on September 7th. Three final prototype models were constructed and displayed alongside the structural analysis, concept and research of each tower. Martin Henn and Moritz Fleischmann presented the results, allowing viewers to engage and discuss the design results of the eight-week period.

Preliminary sketches, drawings and renderings from the mid-review and final review were also included in the exhibition, displaying a full perspective of the DRX 2012. The Final Exhibition took place in the Dog Ear Films studio of Andreas Henn in central Berlin.
3.3 // DRX 2012 RESULTS  PROTOTOWERS

ProtoTower01
Modular Saddle Shell-Structure

ProtoTower02
Singly-Periodic Shell Structure

ProtoTower03
Ultra-Lightweight Spaceframe Structure

Hannes Lechner (Uni Innsbruck)
Sunghyun Park (HENN)
Faniry Razafindrazaka (FU Berlin)

Michael Mülhaus (TU München)
Nils Seifert (TU München)

Agata Kycia (HENN)
Danae Polyviou (TEUFFEL Eng. Consultants)
Anna Wawrzinek (FU Berlin)
The technique of “Form-finding” – the method of finding geometric form through the application of structural forces - is not a novel concept in the field of architecture. Largely recognized for his contribution to the Olympic Stadium in Munich, architect Frei Otto embodies the aesthetic and logistical principles of form-finding in design. The German engineer, Sergio Musmeci (1926-81) is also a central figure in the study of form-finding as seen in his viaduct constructed over the Basento River (1967-74) in Potenza. Traditionally in architecture, form-finding has largely been applied to horizontal structures such as large span roof constructions. Extensive research of previous form-finding structures was carried out and considered in the calculations and prototype development. This has led to the development of a vertical shell structure based on the same force inversion principle that guided the design of prominent compression structures such as the Sagrada Familia in Barcelona or Heinz Isler’s Shells in Switzerland.

This prototype is based on a concrete shell structure, developed by a vertical arrangement of modular saddle-shaped components. The shape of each component was computed as a tension-active system by spring-energy minimization similar to a soap-film model in the real world. Similar to these soap-films, the shape of each module depends largely on the geometry of a fixed boundary. In a following step, calculations of boundary conditions, spatial qualities, building form and elements were reviewed against the results of structural analysis. By changing these boundary conditions a high degree of geometric variation and structural performance was achieved in each component. An extensive test of the structural capacities of individual modules as well as larger assemblies was carried out computationally to determine critical stress accumulations and identify regions for the introduction of openings in the shell. In a following step, slabs were introduced to serve as horizontal stiffeners, preventing the entire system from buckling. The result is a very light shell structure of 2m maximum thickness at the bottom that functions structurally without the use of a central core.

The Italian engineer, Sergio Musmeci (1926-81) is also a central figure in the study of form-finding as seen in his viaduct constructed over the Basento River (1967-74) in Potenza. Traditionally in architecture, form-finding has largely been applied to horizontal structures such as large span roof constructions. Extensive research of previous form-finding structures was carried out and considered in the calculations and prototype development. This has led to the development of a vertical shell structure based on the same force inversion principle that guided the design of prominent compression structures such as the Sagrada Familia in Barcelona or Heinz Isler’s Shells in Switzerland.
The project is the result of exploring the architectural potentials of periodic minimal surfaces. Here the surface is realized as a single concrete shell. The spatial and structural properties that result from different variations of this parameterized minimal surface are utilized for different architectural programs.

Mathematically generated minimal surfaces exhibit two interesting properties with regards to their translation into architectural systems. Primarily, the surface can be developed from a small “fundamental patch”. This element can be assembled into a continuous infinite surface. A trivial example is a small plane “patch” that could be assembled into an infinitely large plane.

Here, the double curvature of the surface behaves as a structural element and resists against different vertical and horizontal weight forces. Additionally, this type of minimal surface divides the adjacent space into two congruent spaces. After an extensive research of methods of modelling minimal surfaces a tool was developed to investigate the extent to which minimal surfaces can be altered to meet various programmatic requirements without compromising structural and functional integrity with regards to high-rise structures.

The main structural element of the tower is the concrete shell. The design features a double curvature surface that shapes the shell and interconnects at the centre to support the structure and prevent buckling.

In the prototype model, the lower section of the structure holds large contiguous floor areas which function as office spaces. The shell provides natural ventilation and lighting through its inherent minimal holes. In the upper section, the structure transforms into a triple tower with residential / hotel use.

Michael Mülhaus (TU München)  
Nils Seifert (TU München)
The design concept of this Prototower was derived from the formations of soap film. In the physical world, soap film consumes the least amount of surface area given a certain boundary. Here we investigated the formation of soap film under special boundary curves. The emergent formation of spatial minimal paths along the edges of multiple minimal surfaces formed the base for this research.

These minimal paths can be considered as curve networks which consist of linear elements with a shortest overall length between all boundaries.

The main structure of the tower is a three-dimensional space frame, which was created using minimization methods and shortest path algorithms. Together with the concrete slabs, the emergent network forms a stiff system that can substitute conventional structural solutions. This stable structure allows the space frame to stand without a central core. This feature gives the tower maximum freedom when choosing an interior program as well as superior ventilation throughout.

Similar to foam bubble formations in nature, every node of the structure has three elements that meet at a 120 degree angle. This is a great advantage for the design concept of this Prototower was derived from the formations of soap film. In the physical world, soap film consumes the least amount of surface area given a certain boundary. Here we investigated the formation of soap film under special boundary curves. The emergent formation of spatial minimal paths along the edges of multiple minimal surfaces formed the base for this research.

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3.7 // DRX 2012 RESULTS STRUCTURAL ANALYSIS

ProtoTower01
Maximum Deformation 2.5m

ProtoTower02
Maximum Deformation 1.4m

ProtoTower03
Maximum Deformation 2.5m

3.8 // DRX 2012 RESULTS MODEL SCALE 1:1000

ProtoTower01
Modular Saddle Shell Structure

ProtoTower02
Singly-Periodic Shell Structure

ProtoTower03
Ultra-lightweight Spaceframe Structure
4.1 // DRX 2012 TEAM PRINCIPALS

Martin Henn, Dipl.-Arch., M.S. AAD
DRX Host / HENN Design Director
(ETH Zürich, Columbia University)

Martin Henn studied architecture at the University of Stuttgart and at the ETH Zürich. He received his Master's Degree in Architecture from the ETH, Zürich in 2006, and his Post-Professional Master of Advanced Architectural Design from Columbia University, New York in 2008. Prior to HENN, he was working for Zaha Hadid Architects (London) and Asymptote Architecture (New York). He has been a regular studio and seminar instructor at the ETH in Zürich, at Columbia University as well as at the TU Dresden.

Links:
www.henn.com
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Dipl.-Ing. Moritz Fleischmann, M. Arch.
DRX Director / HENN Research Director
(University of Stuttgart, AA, ETH Zürich)

Moritz Fleischmann is a Ph.D. researcher at the Institute for Computational Design (ICD), Stuttgart University. His research focuses on the influence of novel computer-based modeling techniques such as physics-based modeling on design methodology in architecture. He studied architecture at the RWTH Aachen (Germany) and the ETH Zürich (Switzerland). He received his M.Arch. Degree from the "Emergent Technologies & Design" program at the Architectural Association in London. In 2012 he was appointed HENN's Head of Research.

Links:
www.henn.com
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HENN Founder + CEO
(MIT, TU Dresden)

Gunter Henn was born in Dresden in 1947 and studied architecture and structural engineering in Munich and Berlin. He is the chairman of HENN. He founded the office in Munich in 1979 and is the successor of the office of Walter Henn. Since 1994, Gunter Henn has been a visiting professor at the Massachusetts Institute of Technology (MIT) in Cambridge. Gunter Henn manages the chair in industrial construction and the Centre for Knowledge Architecture at the Technical University of Dresden.

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**Prof. Dr. Toni Kotnik**
Architect
(University of Innsbruck, ETH Zürich)

Toni Kotnik is assistant professor at the Institute for Experimental Architecture at the University of Innsbruck and lecturer at the Chair of Structural Design at the ETH Zürich. He studied architecture and mathematics at ETH Zürich, the University of Tübingen, and the University of Utah, and received his doctoral degree from the University of Zürich. He was principal researcher at OCEAN design research network, adjunct assistant professor at the University of Applied Sciences in Lucerne, CH, and studio master at the Emergent Technology and Design program at the Architectural Association in London, UK. His practice and research work has been published internationally and is centered on the integration of scientific knowledge into the design process with focus on the relationship between digital architectural design, geometry and material behavior.

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Patrick Teuffel (born 1970 in Aachen) is educated as a structural engineer and started his career at Arup in London. From 1999-2003 he carried out his PhD about the application of adaptive systems in architecture and engineering at the University of Stuttgart. In 2003 he founded TEUFFEL ENGINEERING CONSULTANTS, an engineering consultancy with focus on special and lightweight structures. Since 2008 he has been Professor for Architectural Engineering at TU Delft, and since 2012 he is Professor for Innovative Structural Design at Eindhoven University of Technology, with research focus on light and adaptive structures.

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Konrad Polthier is a Mathematical Geometry Processing Group Professor and head of the Mathematical Geometry Processing group at the Institute of Mathematics at Freie University Berlin. He is a full professor of Mathematics with research interests in the areas of mathematical geometry processing, discrete differential geometry and mathematical visualization. As chair of the Berlin Mathematical School (BMS), his current efforts in teaching and education focus on our more than 150 international master and PhD students. His efforts as director of the Institute of Mathematics and former member of the academic senate of Freie University Berlin target at improving the internal workflows of the institute and university in order to provide a fruitful ground for an excellent research and teaching environment.

Links:
http://www.polthier.info/
http://geom.mi.fu-berlin.de/index.html

01. Gergonne / Balanced tension vectors on a discrete Gergonne Surface.
02. Bubble / Experimental design of the Penta Surface, a closed bubble of Genus 5.
Tobias Nolte joined Gehry Technologies in 2008 as a technical consultant. After leading consulting engagements throughout Europe, he was appointed director in Europe in 2011, where he began leading a team of architects, engineers and builders in the implementation of concurrent design systems to improve design, engineering and construction performance. Areas of interest include design computation, integrated product and process design, construction automation, concurrent design and Cloud technologies.

Mirko Becker is a Berlin-based architect and computational designer. He is a Visiting Professor for Architecture and Performatives Design at the Staatliche Höhere Fachschule für Gestaltung (HfG) Stuttgart. Over the last ten years, Becker worked as a specialist for Foster & Partners, Kohn Pedersen Fox, Zaha Hadid Architects, and taught at the AA Diploma Unit 1, AADRL, University Kassel.

Tobias Nolte, Director Europe
(Gehry Technologies)

Eva Hinkers is Head of Structural Planning at ARUP in Düsseldorf. After studying structural engineering at RWTH she worked for Bovis in London before joining ARUP. Hinkers is now the leader of ARUP’s Internal Europe Buildings Practice team.

Eva Hinkers, Director
(ARUP Deutschland GmbH)

Alex Reddihough received a Master’s Degree in Architectural Engineering from Cardiff University in 2007. He has been working for Arup in London since as part of a multidisciplinary building design team, concentrating on projects with complex geometry, high-rise buildings and seismic engineering. Key projects include the new diagrid roof at Kings Cross station in London, the Serpentine Gallery summer pavilion of 2008 with Gehry, Beirut Terraces Tower and Complexo Cultural Luz, Sao Paulo with Herzog and de Meuron, Torre Reforma S09 in Mexico City, and the Haikou Tower with HENN.

Alex Reddihough, Structural Engineer
(ARUP London)

Peter Debney is a structural engineer with more than twenty years of experience in the construction industry. Specializing in computing applications, Peter works on engineering analysis, design, and BIM software products. Concurrently, he designs structures ranging in size from houses to oil refineries. Peter is currently the Application Specialist for the Oasys structural and crowd modeling tools, assisting practicing engineers worldwide and developing the next generation of design software. Peter is teaching a GSA workshop at the DRX 2012 addressing the topic, “Form Follows Force – Soap Films and Geometric Optimization.”

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Daniel Lordick is a visiting professor at the TU Berlin. He holds a PhD from Prof. Dr. Klaus Meier from Karlsruhe. His research and studies have made him a prominent figure working at the intersection of architectural design, geometry, visualization and mathematical modeling.

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Daniel Lordick, Professor
(TU Berlin, TU Dresden)
4.5 // DRX 2012 TEAM RESEARCHERS

Agata Kycia, MSc. Arch.
DRX Researcher / HENN Architect (IAAC, TU Delft)

Hannes Lechner, BSc. Arch.
DRX Researcher / Supertex Researcher (University of Innsbruck)

Michael Mühlhaus, BSc. Arch.
DRX Researcher / muehlseife Founder (TU München)

Sunghyun Park, M. Arch.
DRX Researcher / HENN Architect (University of Pennsylvania)

Danae Polyviou, M. Eng.
DRX Researcher / Teuffel Eng. Consultants (University of Bath, Anhalt University IMS)

Faniry Razafindrazaka, Dipl.-Math.
DRX Researcher / Ph.D. Researcher (Freie University, Berlin Mathematical School)

Agata Kycia studied architecture at the Warsaw University of Technology and received her Master’s Degree from both WAT (Digital Tectonics) and TU Delft (Hy-perbody). Following her studies, she collaborated on several projects with ONL (Oosterhuis_Lenard) and NIO (Rotterdam) in parallel to teaching in the field of computational design (Warsaw University of Technology, TU Delft). She now works as a designer at HENN StudioB in Berlin.

Links:
www.agatakycia.com
www.henn.com

Hannes Lechner received his Bachelor’s Degree in architecture at the Leopold Franzens University Innsbruck. While working for the Institute for Experimental Architecture at the university, Hannes worked with several rapid prototyping techniques and held workshops for Rhino / Grasshopper and Maya. Working for the institute also led to his employment at Supertex, a company which develops and engineers carbon fiber structures for architectural purposes. At Supertex Hannes has been working in modeling, scripting and fabrication sectors.

Michael Mühlhaus is an architecture student at the TU Munich. He recently received first prize with Nils Seifert for their self-programmed urban planning tool in the renowned AufGebaut national competition. Michael and Nils work together to consult various offices and develop computational design strategies for architecture projects.

Link:
www.muehlseife.de

Sunghyun Park studied architectural engineering at Yonsei University in South Korea and received his Master Degree from PennDesign at University of Pennsylvania in the U.S. He also studied computational design methodology based on building performance at PennDesign. Prior to Studiolo, Sunghyun worked at JohsunYoung Architect Office (UBAC), G.A.A Architects and AandD in Seoul, in addition to Phu Hoang Office in NYC.

Links:
www.sunghyunpark.com
www.henn.com

Danae Polyviou graduated in 2011 with honors from the University of Bath with a M.Eng. Degree in Civil and Architectural Engineering. She is currently extending her studies with a part-time master degree on Membrane Structures at Anhalt University (IMS). Since December 2011 she is working as a structural engineer at Teuffel Engineering Consultants in Stuttgart, Germany.

Link:
www.patrick-teuffel.com

Faniry Razafindrazaka is a member of the BMS (Berlin Mathematical School). He received his Master Degree from the Freie University in Berlin. He now works as a PhD student with the Mathematical Geometry Processing group at the Freie University since 2009. His current focus comprises the visualization of regular tiling on arbitrary compact surfaces.

Links:
http://geom.mi.fu-berlin.de/index.html
http://www.matheon.de/
Nora Graw studied architecture at the Technical University Braunschweig and the University of Applied Arts in Vienna, where she graduated from Greg Lynn’s Master Class in 2009. Prior to StudioB she worked for Cloud9 and Enric Ruiz Geli in Barcelona, where she directed the office’s research agenda. Nora also taught a Diploma Unit at the Architectural Association in London.

Link: www.henn.com

Sarah Roberts graduated with high honors from the University of California Berkeley with a Bachelor of Arts Degree in Architecture. She also completed programs at California Polytechnic Uni. in San Luis Obispo and Scuola Leonardo da Vinci in Rome. Prior to StudioB, Sarah co-founded pinkcloud.dk (New York) and worked at Henning Larsen Architects (Copenhagen) and SAAT (San Francisco).

Link: www.henn.com
www.pinkcloud.dk

Nils Seifert is currently studying architecture at the TU Munich. He recently received first prize with Michael Mühlhaus for their self-programmed urban planning tool in the renowned AufItGebaut national competition. Nils and Michael work together to consult various offices and develop computational design strategies for architecture projects.

Link: www.muehlseife.de

Anna Wawrzinek is a Ph.D. researcher at the Mathematical Geometry Processing Group of the Freie University Berlin. She obtained her Diploma Degree in Mathematics from the Freie University in Berlin in 2011. Currently she deals with the investigation of the power of the Catmull-Clark subdivision surfaces for physical simulation.

Links:
http://geom.mi.fu-berlin.de/index.html
http://www.matheon.de/

Anna Graw, Mag. Arch.
DRX Administrator / HENN Architect
(University of Applied Arts in Vienna)

Sarah Roberts, B.A. Arch.
DRX Communications / HENN PR
(TU Delft, UC Berkeley)

Nils Seifert, BSc. Arch.
DRX Researcher / muehlseife Founder
(TU München)

Anna Wawrzinek, Dipl.-Math.
DRX Researcher / Ph. D. Researcher
(Freie University Berlin)
6.1 // DRX 2012 LOCATION + FACILITIES

The DRX 2012 took place at HENN StudioB on the 9th floor of Alexanderstraße 7, known as the “Haus des Reisens” high-rise. The building overlooks Alexanderplatz in central Berlin. The address follows:

HENN StudioB
Alexanderstraße 7, 9th Floor
10178 Berlin, Germany

Internal expertise, IT infrastructure, facilities, and materials for model-building are provided by HENN for all DRX functions. Researchers have their own workstations to execute DRX experiments amidst the competition environment at HENN StudioB.

6.2 // ABOUT HENN

HENN is an international architectural practice based in Germany with more than 50 years of experience in designing culture, education, production, and research and development buildings. The office is managed by Prof. Dr. Gunter Henn and nine partners. Approximately 330 architects, planners and engineers work in the HENN offices in Munich, Berlin, Beijing and Shanghai.

HENN STUDIOB is the Berlin based design and research studio of HENN. Located on the ninth floor of the “Haus des Reisens” overlooking Alexanderplatz in central Berlin, HENN StudioB hosts the DRX 01. The studio combines novel concepts and design strategies with the know-how and expertise of HENN. Managed by Martin Henn and dedicated to innovation of the field, StudioB performs as an open platform of exchange between HENN, academia and experts from various fields.

HENN Beijing Office
HENN Shanghai Office
HENN Munich Office
HENN Berlin Office

HENN is an architectural office with strong links to academia, and we would like to emphasize the importance of scholarly discussion throughout the DRX. As a professor at the TU Dresden, Prof. Dr. Gunter Henn with the Center for Knowledge Architecture in Dresden investigate different methods for channeling information using novel techniques such as programming, shape grammar and netgraphing. Professor Henn joins the DRX for key presentations and discussions.
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Location of HENN StudioB on Alexanderplatz, Berlin.

DRX 2012 / Behind the Scenes at StudioB / Photos by Sunghyun Park